Technical Memorandum

No. K-28/64

THE SUPPORTING ARMS MODEL

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Computation and Analysis Laboratory

U. S. Naval Weapons Laboratory

Dahlgren, Virginia

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U. S. NAVAL WEAPONS LABORATORY

TECHNICAL MEMORANDUM

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While the contents of this memorandum are considered to be correct, they are subject to modification upon further study.

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ABSTRACT

The U. S. Naval Weapons Laboratory, Dahlgren, Virginia, has developed a detailed event type simulation of the Supporting Arms Phase of an amphibious operation. The model has been developed for research use in making studies concerning the supporting arms phase of an amphibious operation during the pre-D-day and D-day (pre-H-hour) time period in a limited war setting, and for Fleet Operaters use to determine supporting arms requirements for an amphibious assault. Programmed for the IBM 7030 (STRETCH) digital computer, the model simulates the naval gunfire and air support portions of the amphibious operation. Provisions are being made to simulate attrition to friendly attack aircraft. The model is currently operational and provides for considerable flexibility of input data and for a wide variety of studies and applications.

FOREWORD

The U. S. Naval Weapons Laboratory, Dahlgren, Virginia, is responsible for the development and application of computer models in the field of amphibious warfare. This work is supported and directed by the Office of the Chief of Naval Operations (OP-06C), and is currently being conducted under BUWEPS Task Assignment R520-00-001/210-1/F018-02-01.

INTRODUCTION

The Supporting Arms Model is a detailed event-type simulation which has been formulated to simulate, separately or combined, the naval gunfire and air support portions of an amphibious operation during the pre-D-day and D day (pre-H-hour) time period in a limited war setting. Artillery fire support has been omitted from the simulation because of the pre-H-hour constraint. If this capability is needed in a special study, it can be played to a limited degree by inputting characteristics of artillery pieces as characteristics of firing units on ships. Provisions are being made to simulate attrition to friendly attack aircraft by enemy ground air defense installations during strikes on enemy targets. The model has been programmed for the IBM 7030 (STRETCH) digital computer.

The purpose of this report is to describe briefly each of the major portions of the model, to discuss areas of application, and to inform potential "users" of input requirements and resulting output.

TYPE OF MODEL

The Supporting Arms Model is what is commonly referred to as an event type model. It contains 28 tables which are used for descriptive purposes and status updating, and it contains 25 events and two routines which are mathematical representations of the various actions which would take place during an amphibious operation. The elements of the game (ships, aircrafts, targets, etc.) are examined in detail only at times when these actions, called events, take place. When an event (select target, launch aircraft, deliver ordnance, etc.) is initiated, the time to complete the event is computed, the effects of this event or any of the elements of the game are determined, and the entries in the corresponding tables are changed to reflect the results of this event. Events can be stored to take place at specific times, but in general, once the game has started, the event in progress generates future events which are consequences of the action taking place. The model logic arranges the initiation of these future events in order of increasing time. The tables are, thus, dynamic, reflecting the status of each element in the game at all times. It is, therefore, the tables which are examined to determine the status of given elements.

A print-out of any table can be ordered at any time during the play-out of the game. For example, a print-out of the output storage table at time 1400 D-1 indicates those targets which have been "killed", the support ship number or aircraft number which "killed" each target, the amount of ammunition expended by type on each target, and the time each target was engaged by naval gunfire and/or air support. Appendix A provides a list of all tables in

the game, and Appendix B provides a list of all events Appendix C is a flow schematic of the paths the game can take through the various events.

MODEL DOCTRINE

The doctrine upon which the model was written is that contained in NWIP 22-7(A), NWIP 31-3(A), NWP 41(A), NWIP 22-3(A), NWIP 20-1, NWIP 22-2, ATP 4, and LFM-8. Doctrine was also discussed with Marine Corps Officers at the Landing Force Development Center, Quantico, Virginia, and with Naval Officers at the U. S. Naval Amphibious Schools, Little Creek, Virginia.

MODEL CAPACITY

Theoretically, the storage of the computer limits the size of the operation. However, the storage capacity of the IBM 7030 digital computer imposes no realistic constraints. The only constraints in the model are the size of the assault area, limited to 57 x 57 miles, and the number of types of aircraft and naval ordnance, limited to nine types each. If necessary, these constraints can be removed with minor model modification.

DESCRIPTION OF MODEL

a. Operations Area - The operations area is represented in the first quadrant in a Cartesian coordinate system Both the X and Y axes are scaled in units of 100 yards as shown in Figure 1.

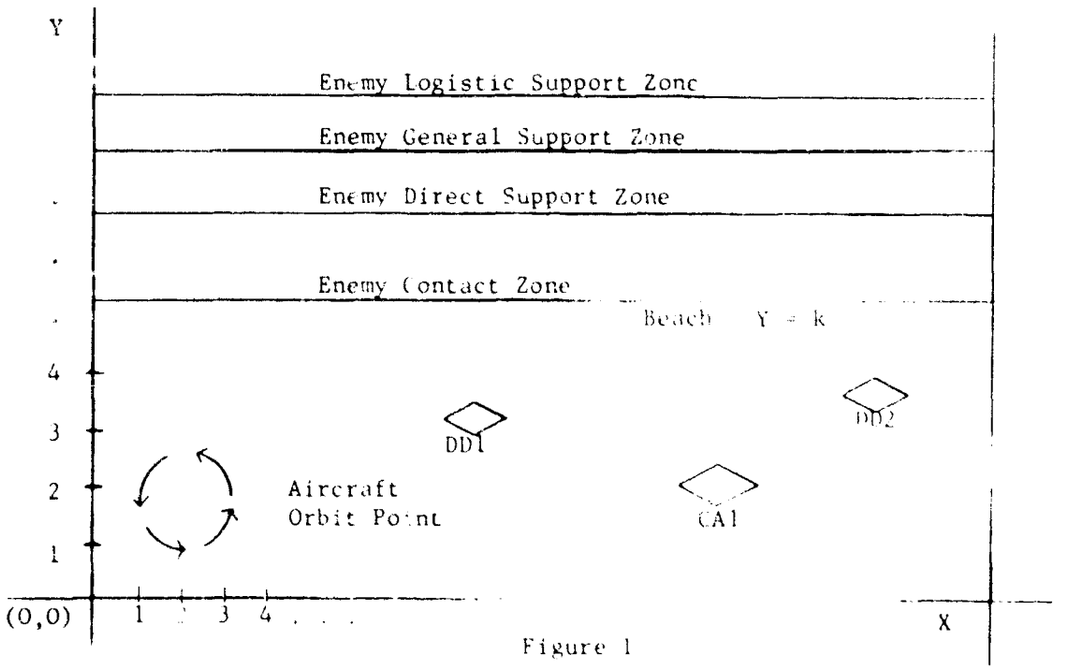


Figure 1

where 1, 2, 3, 4, . . . represent 100, 200, 300, 400, . . . yards respectively. The model provides for 999 units on each axis. Therefore, the operations area represents an area 99,900 x 99,900 yards, which is approximately 57 miles x 57 miles. The beach is represented by the horizontal line Y = k where k is large enough to allow all support ships and A/C orbit points to be placed between Y = 0 and Y = k. The locations of the fire support ships, A/C orbit points and targets are input parameters represented by coordinates (X, Y). In this manner, the distance between ships and targets or orbit points and targets can easily be determined. The distance of aircraft carriers and land bases from the beach are usually of such magnitudes as to place them outside our coordinate system (possibly in excess of 100 miles). This poses no real constraint, for the distance of each carrier or land base from the operations area is represented as an input parameter. In this manner, the flying time between carriers and targets or orbit points can be determined

Enemy defenses are separated into four zones parallel with the beach. These zones are as follows:

(1) Contact Zone

(2) Direct Support Zone

(3) General Support Zone

(4) Logistic Support Zone

The depth of each zone is an input parameter and can be varied for any particular study. (See Appendix D, Tab A)

b Targets - Each target is described in a table by the use of input parameters. Any descriptor pertinent to defining the target must be included. Examples are target size, location, type, and priority. Also, the order of preference of the various ordnances that can be used effectively against the target must be indicated. (See Appendix D, Tab E)

Although each target which will take part in the game must be initially described in a table, it need not be activated (brought into the game) initially. A target can be activated in one of three ways:

(1) It can be activated initially

(2) It can be activated at a specific time

(3) It can be activated randomly during the play of the game.

By activating targets using (2) or (3) ab ?, surveillance acquisition rates and/or enemy build-up rates can be simulated. Once a target is activated, it is considered "known" It is subject to attack by air and/or naval gunfire.

A target can be given specific coordinates (X, Y), or it can be assigned random coordinates within its zone of action. A combination of the two methods can be used in a game, inputing specific locations for some targets and randomly determining the locations of others.

c. Naval Gunfire - Each ship is described in a table by the use of input parameters as to the number of independent fire support systems (called firing units) on board, coordinates of location, number of rounds of each type of ordnance, etc. (See Appendix D, Tab B.) Furthermore, each firing unit is described in a table indicating the ship number on which it is located, size of ordnance, maximum effective range, etc. Each type of naval ordnance is also described in a table as to the number of rounds to fire for effect on point and area targets, estimated number of rounds to adjust on point and area targets, estimated time required to adjust on point and area targets, ordnance reliability, etc. (See Appendix D, Tab J.) Provisions have been made to accommodate up to nine types of ordnance in a single computer run. This allows for a variety of warhead and fuse mixes. For example, the nine types of naval ordnance played in a particular game could be as follows:

Type 1 - 5" Common, base detonating fuse

Type 2 - 5" H. C., variable time fuse

Type 3 - 5" H. C., point detonating fuse

Type 4 - 6" A. P., base detonating fuse

Type 5 - 6" H. C., variable time fuse

Type 6 - 6" H. C., point detonating base

Type 7 - 8" H. C., base detonating fuse

Type 8 - 8" H. C., variable time fuse

Type 9 - 8" H. C., point detonating fuse

The times each ship is to be activated (brought into the game) and the times that each is to be removed are also input parameters in the aforementioned tables. In this manner, ships can be activated and removed at predetermined times throughout the course of the

game. Once activated, a ship is stationary. However, if it is desired to move a ship to a new fire support location at a specific time, the ship can be removed from its old location in sufficient time to enable it to arrive at its new location, at which time it can again be activated.

Times for all active support ships to commence and cease fires are input parameters. Thus, all naval gunfire can be stopped at specific times such as during preplanned air strikes, hours of darkness, etc., and resumed later in the game. (See Appendix D, Tab G.)

When a support ship is activated, either by single ship activation or by naval gunfire activation of all active support ships, a target search is necessary for each firing unit on the ship. The target search is based on the following criteria: target priority, ordnance preference, zone of responsibility in which the target is located, and whether or not the target is in a restrictive fire zone. That is, each firing unit searches for the highest priority target in its zone of responsibility which is not in a restrictive fire zone against which its ordnance can be used effectively. Once targets are selected initially for each firing unit, the model generates new events which are consequences of the fires for effect as follows: Time is updated at the end of each fire for effect and the effects are assessed and recorded. If the target is destroyed, the firing unit searches for a new target. If the target is not destroyed, the firing unit can fire subsequent fires for effect, by-pass the target, or transfer the target to air support. If either of the latter two decisions are made, the firing unit searches for a new target. This process continues for each firing unit on each fire support ship until that ship is out of ammunition, removed from the game, or until all naval gunfire is ceased. The maximum number of fires for effect to fire at a target and the decisions to by-pass the target or transfer it to air support after the maximum number of fires for effect are input parameters, being functions of the target type.

d. Air Support - The air support portion of the model consists of preplanned air strikes and alert status air strikes. In general, all pre-D-day strikes will be of the preplanned type while D-day strikes can be of either type. The model does have the capability to play alert status aircraft during the pre-D-day period if this capability if needed for a specific study.

Each aircraft is described in a table by the use of input parameters as to the carrier or land base to which the aircraft is assigned, the orbit point, if any, to which this aircraft will be assigned, time the aircraft should be activated (brought into the game), standard ordnance load, aircraft cruising speed, etc. (See Appendix D, Tab D.)

Each type of air ordnance is also described in a table as to the number of ordnance delivered per pass area and point targets, delivery altitude for point and area targets, ordnance reliability, etc. (See Appendix D, Tab L.) In order to allow for a variety of aircraft ordnance and fuse combinations, provisions have been made to accommodate up to nine types in a single computer run.

The number of aircraft used for a strike on a target can vary from one to four depending upon the characteristics of the target and aircraft availability. The maximum number and minimum number of aircraft to use for a strike on any target that is subject to air attack are input parameters in the target table. When an air request is received for ground-alert or air-alert aircraft, or when a pre-planned assignment is made, if the maximum number of aircraft specified for a strike against the target is not available but the minimum number requirement is satisfied, those that are available are assigned to the target.

The times that each pre-planned strike period is to commence, the number of aircraft to be employed during the strike period, and target numbers of specific targets to be attacked are input parameters. If specific targets are not listed for the pre-planned strike period, the model will select targets of highest priority of those that are active. In reality, these assignments would take place sometime prior to the actual strikes based on "known" targets at that time. If this course of action is followed, the time that the assignments would be made must be specified. (See Appendix D, Tab F.)

For each pre-planned air strike period, aircraft are launched from either land bases or aircraft carriers in sufficient time to enable them to be over the target area at the time specified. Following each pass over each target, damage is assessed and recorded and all pertinent tables are updated. If an aircraft does not make a successful pass on the target to which it is assigned, subsequent passes will be made until the target is destroyed or the aircraft's ordnance and/or flying time have been exhausted. If an aircraft makes a successful strike on the target to which it is assigned, and if ordnance load and flying time permits, other strikes may be made. Targets for these subsequent strikes will be selected from those that are of the highest priority. Following expenditure of ordnance and/or flying time, the aircraft is returned to its base, landing only with the ordnance permitted.

Alert status aircraft are of two types, ground-alert and air-alert. The difference being that ground-alert aircraft await target assignments at the base or carrier to which they are assigned while air-alert aircraft await target assignments at various orbit points near the beach. When an air request is received for ground-alert

aircraft, aircraft, if available, are launched and sent directly to the target. The procedure is then identical with that followed for aircraft making a pre-planned air strike.

The time periods when air-alert aircraft are to be on station (at orbit points) as well as the number of aircraft for each time period are input parameters. (See Appendix D, Tab H.)

At the beginning of each air-alert time period, the number of aircraft to be on station, if available, are launched. Once on station, these aircraft await target assignment. When an air request is received, the available aircraft with optimum ordnance load versus target is assigned to the target. Following each pass on the target, damage is assessed and recorded and all pertinent tables are updated. If the pass is not successful, the aircraft makes subsequent passes until the target is destroyed or until ordnance and/or flying time is exhausted. If the strike is successful and if flying time and ordnance permit, the aircraft is returned to its orbit point to await further target assignments.

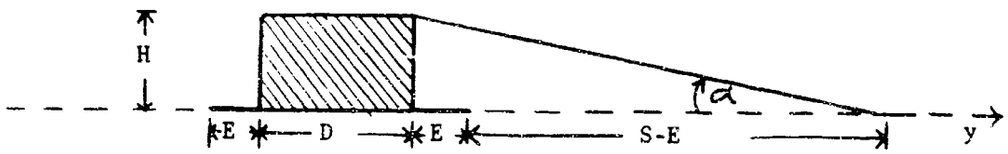
Air alert aircraft, at the end of their combat flying time, are replaced by ground alert aircraft. If prior to this time an aircraft expends all its ordnance, another aircraft is immediately launched to replace it.

When an aircraft is returned to its carrier or base for rearmament or refueling, it is placed in an inactive status. The time to reactivate each aircraft is an input parameter in the aircraft table. When the reactivation time has elapsed the plane is again placed in an active status loaded with the standard ordnance load for this aircraft.

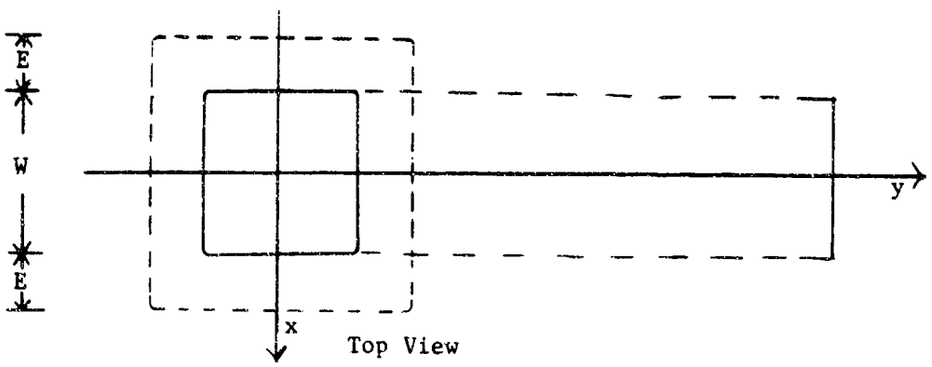
In order to insure that friendly attacking aircraft are not hit by naval gunfire projectiles, all pre-planned air strikes should be planned to occur during periods when naval gunfire is ceased. During an alert status air strike, a restrictive fire plan is put into effect. This restricts firing naval projectiles which would pass through the rectangular parallelepiped in which the attacking aircraft is maneuvering. The plan is put into effect when the aircraft arrives in the target area and stays in effect until the strike is completed. The base altitude of the zone is dependent upon the ordnance being delivered and the target type. The width and length of the zone are dependent upon the striking flight path of the aircraft. These dimensions are input parameters.

e. Point Target Hit Assessment - In the computation of the number of hits inflicted on a point target from an air delivery of N ordnance of a certain type, the target is placed at the origin of a Cartesian axis Oxy. The shots or bursts are then assumed to

form an uncorrelated bivariate normal distribution with means $\mu_x = \mu_y = 0$ and standard deviations σ_x and σ_y in the x and y directions, respectively. The dimensions of the target are increased on all sides by the effective miss distance (EMD) of this ordnance versus this target, and the target is then projected onto the xy plane, the projection being a function of the target height and depth and the angle of fall of the ordnance. This is shown in Figure 2 below.



Side View



Top View

Figure 2

H = target height

W = target width

D = target depth

E = effective miss distance

S = shadow or projection depth

α = angle of fall of the ordnance

Designating W' = E + (1/2) W, D' = E + (1/2) D, and S' = S - E, the single shot hit probability (SSHP) is represented by the following integrals.

$$P_1 = \frac{1}{2\pi\sigma_x\sigma_y} \int_{-D'}^{+D'} \int_{-W'}^{+W'} e^{-\frac{1}{2}\left[\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right]} dx\, dy$$

$$P_2 = \frac{1}{2\pi\sigma_x\sigma_y} \int_{S-E}^{+\infty} \int_{-\frac{W}{2}}^{+\frac{W}{2}} e^{-\frac{1}{2}\left[\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right]} dx\, dy$$

If $S > E$, $SSHP = P_1 + P_2$

If $S \leq E$, $SSHP = P_1$

The number of reliable ordnance and of these, the number of hits are determined by Monte Carlo sampling

The deflection probable error (DEP), the range probable error (REP), the angle of fall for each air ordnance, and the effective miss distance (EMD) for each air ordnance versus each type of point target are input parameters. The DEP, REP, and the angle of fall are functions of the ordnance type, release altitude, release speed, director system and the angle of delivery. The DEP and REP are used to compute σ_x, total deflection dispersion and σ_y, total range dispersion as follows:

$$\sigma_x = (1.48)(DEP)$$

$$\sigma_y = (1.48)(REP)$$

In the computation of the number of hits inflicted on a target from the delivery of N rounds of naval gunfire ordnance of a certain type, the same distribution is assumed, but the target is not necessarily considered to be at the origin Oxy. The target is placed randomly within a circle of radius R centered at the origin. R is designated as the spotter's adjustment limit, for it simulates the spotter's adjustment of the mean point of impact (MPI) of the N rounds to within some specified distance from the target. R is an input parameter and can be specified as zero, if desired, to simulate perfect spotter's adjustment.

Letting h and k represent the randomly placed x and y coordinates of the target, in relation to the MPI, the SSHP is represented by the following integrals:

$$P_1 = \frac{1}{2\pi\,\sigma_x\,\sigma_y} \int_{k-D'}^{k+D'} \int_{h-W'}^{h+W'} e^{-\frac{1}{2}\left[\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right]} dx\,dy$$

$$P_2 = \frac{1}{2\pi\,\sigma_x\,\sigma_y} \int_{k+D'}^{k+D'+S-E} \int_{h-\frac{W}{2}}^{h+\frac{W}{2}} e^{-\frac{1}{2}\left[\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right]} dx\,dy$$

If $S > E$, $SSHP = P_1 + P_2$

If $S \leq E$, $SSHP = P_1$

The number of reliable ordnance and, of these, the number of hits are determined by Monte Carlo sampling.

There are two major sources of dispersions of naval projectiles, ammunition dispersion and firing system dispersion. Ammunition dispersion is caused by the heterogeneity of ammunition, and firing system dispersion is caused by errors in the fire control system on the ship. Deflection ammunition dispersion, σ_{x1}, is assumed to be a constant mil error and is an input parameter for each size of naval ordnance. Range ammunition dispersion, σ_{y1}, is an input parameter for each size of naval ordnance in 1000 yard increments. Deflection and range firing system dispersion, σ_{x2} and σ_{y2}, are assumed to be constant mil errors and are input parameters for each firing system on each ship. The above dispersions are combined to yield σ_x, the total deflection dispersion and σ_y, the total range dispersion as follows:

$$\sigma_x = \sqrt{\sigma_{x1}^2 + \sigma_{x2}^2}$$

$$\sigma_y = \sqrt{\sigma_{y1}^2 + \sigma_{y2}^2}$$

The angles of fall are input parameters for each size of naval ordnance in 1000 yard increments. Also, the EMD's for each type of naval ordnance versus each type of point target are input parameters.

f. Point Target Damage Assessment - Damage to point targets is assessed using the conditional kill probability concept. For each ordnance type (both air and naval gunfire) versus each target type, the conditional kill probability, that is, the probability of kill given a hit, is an input parameter. For each hit on a point target, determined by the aforementioned methods, Monte Carlo sampling is employed to determine if any of the hits is a kill.

g. Area Target Hit and Damage Assessment - The mean area of effectiveness (MAE) for each type ordnance versus each type area target is an input parameter. The MAE is assumed square, and thus, any round of ordnance falling within $(1/2)\sqrt{MAE}$ of an area target is considered a hit, covering or killing some percentage of the target. This is illustrated in Figure 3 below.

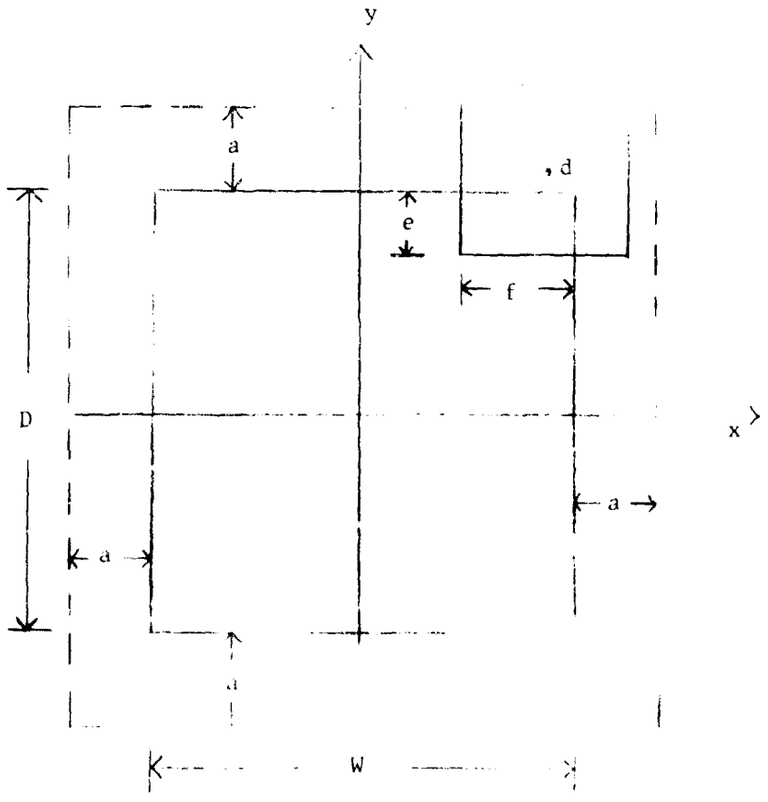


Figure 3

$a = (1/2)\sqrt{MAE}$

D = target depth

W = target width

d = ordnance hit point

eXf = area of target killed by this hit

(eXf)/(WXD) = percent of target killed by this hit

The number of hits inflicted on an area target from an air delivery or naval gunfire delivery of N ordnance of a certain type is determined by increasing the dimensions of the target on all sides by $(1/2)\sqrt{MAE}$ (as shown in Figure 3) and then employing the same methods employed for point targets. The only difference is that the heights of area targets are assumed to be zero, and thus there is no projection onto the xy plane due to angle of impact. Each hit thus determined is placed randomly in the target area, $(W+\sqrt{MAE}) X (D+\sqrt{MAE})$, and the total area covered or killed is determined by summing the areas covered by each hit, allowing for overlaps. Percent coverage is then determined by dividing the area covered by the area of the target. For each target, the per cent coverage necessary to kill the target is an input parameter. The target is recorded as killed when the per cent coverage is greater than or equal to the input requirement.

INPUT REQUIREMENTS

Input requirements for the Supporting Arms Model can be divided into two categories, technical data and operational data.

Technical data can be supplied by the U. S. Naval Weapons Laboratory. Such data include firing system dispersion and ammunition dispersion data for naval gunfire, dispersion data for air released ordnance, target vulnerability and weapon lethality data for both naval and air delivered ordnance against various types of targets, etc. These data are being compiled from Bureau of Ordnance and Bureau of Weapons publications and other pertinent technical reports. They will be updated as more valid reports become available and as new ordnance are developed and reports stating their characteristics and effectiveness become available.

Operational data must be supplied by the "user" or "customer" for a particular operation or plan of action. Such data include the number of fire support ships, by type, in the operation and the amount of ammunition, by type, on each ship, the number of aircraft, by type, in the operation and the standard ordnance load for each, intelligence data concerning enemy targets, etc. Appendix D is a

detailed listing of operational data needed to exercise the model for operational use. It should be noted that in addition to the data in Appendix D, some liaison will be required with the "customer" prior to computer runs to insure that the problem is understood.

RESULTS

The print-out of every table at any given time yields the status of each element in the game at that time. However, this is both costly and time consuming. It is for this reason that several tables are used to summarize output. These output tables contain the following type of information: the total amount of each type of air and naval ordnance expended, the target numbers of "killed" targets, the amount of ordnance expended on each target, the number of missions flown by each aircraft, etc

As a means of illustration, one output table, the Output Storage Table, is shown in detail below. The entries (OS1) in this table are listed chronologically. The information in this table is listed for each naval gunfire and air mission.

OUTPUT STORAGE TABLE (OS)

OS1	XXXXX	Time this mission was initiated
OS2	XXXXX	Time this mission was completed
OS3	XXX	Target number of the target being attacked in this mission.
OS4	XXX	Firing unit or aircraft number of the attacking element. If it was a naval gunfire attack, the firing unit number is recorded; if it was an air strike, the lead aircraft number is recorded.
OS5	XXX	2nd aircraft number } If it was an air strike and involved more than one aircraft, the other aircraft numbers are recorded here.
OS6	XXX	3rd aircraft number }
OS7	XXX	4th aircraft number }
OS8	XX	Ordnance number of the type ordnance delivered.
OS9	XXX	Number of rounds delivered during this mission.
OS10	XXX	Number of target hits.

OS11	X.XXX	The single shot hit probability (SSHP) computed in the model for the ordnance delivered during this mission.
OS12	XX	Gun - target range in 1000 yard units if this was a naval gunfire mission.
OS13	X	Status of the target at the end of this mission 0 - target active. 1 - target killed.

It should be noted with emphasis that this is a stochastic model. The results will vary from run to run with the same input data. Therefore, the results from any single computer run have little meaning. Sufficient replications of computer runs must be made to yield a "good" statistical sample and the results must then be analyzed by statistical techniques to determine which output have statistical significance. Of course further analysis must be made to determine which of the statistically significant results have military significance.

AREAS OF APPLICATION

The versatility of the Supporting Arms Model provides for a wide variety of studies and applications. Several areas of application are described below:

a. Weapons effects studies can be conducted to determine the effects of varying the weapons used against a given complex of targets. Studies of this kind would provide comparison data of proposed tables of equipment weapon systems allocations versus operational tables of equipment weapon systems allocations Furthermore, one ordnance would be compared with another as to the effects each would have on a specific target.

b. Studies can be conducted to examine air delivered ordnance planning factors which have been described in documented contingency war plans or operations orders for actual mount-out of amphibious Marine expeditionary forces. This means that targets from the intelligence annex and the air support schedule from the air support annex would be played with various ordnance mixes to determine the expected number of each type required for the operation.

c. Similar studies can be conducted to examine naval delivered ordnance planning factors or a combination of air and naval ordnance planning factors.

d. It is anticipated that a large and comprehensive parameter study will be conducted to generate prediction equations which will serve as an aggregated means of assessing the outcome of various possible confrontations of naval gunfire elements and air support elements with a wide variety of target complexes.

PROBLEM SUBMISSION

All problem submissions should be made to the Chief of Naval Operations (OP-06C), with a copy to Commander, U. S. Naval Weapons Laboratory, Dahlgren, Virginia (Code: KRW).

GLOSSARY

ALERT AIRCRAFT STRIKE PERIOD - A time period during which ground or air alert status aircraft are on station and available for immediate target assignment.

ANGLE OF FALL - The angle between the projectile trajectory at impact and the horizontal or ground plane.

AREA TARGET - In general, a target consisting of several elements (such as a personnel target) whose dimensions are large compared with the "damage radius" of the weapon.

DEFLECTION PROBABLE ERROR (DEP) - The distance on each side of the line passing through the mean point of impact (MPI), parallel to the line of flight, which will, on the average, enclose 50 per cent of the ordnance impacts. It is assumed the MPI is on the target.

EFFECTIVE MISS DISTANCE (EMD) - The EMD of an ordnance in causing a specified level of damage to a particular target element is the maximum distance from the target which the ordnance can hit and cause the specified level of damage.

KILL CRITERION - A definition of the minimum damage level which a weapon must inflict on a target for the target to be considered incapacitated.

KILLED TARGET - A target which is at least damaged by the amount specified by the kill criterion.

MEAN AREA OF EFFECTIVENESS (MAE) - The MAE of an ordnance in causing a specified level of damage to a particular target element is the area over which that ordnance, on the average, will cause the specified damage to the target.

MONTE CARLO SAMPLING - Sampling simulated by the selection of random numbers.

ORBIT POINT - A location near the assault area, out of the range of enemy AA installations, where air alert aircraft orbit while awaiting target assignments.

PASS - A single run by one or more aircraft over a target

POINT TARGET In general, a target consisting of only one element whose dimensions are small compared with the "damage radius" of the weapon.

PRE-PLANNED STRIKE PERIOD - A time period during which pre-planned air strikes occur.

RANGE PROBABLE ERROR (REP) - The distance on each side of the line passing through the mean point of impact (MPI), perpendicular to the line of flight, which will, on the average, enclose 50 per cent of the ordnance impacts. It is assumed the MPI is on the target.

STRIKE - The pass or series of passes made by one or more aircraft when attacking a target.

APPENDIX A

SA TABLES

1	Future Event	FE
30	Output Control	OC
50	Miscellaneous Input	MIT
51	Battle Area	BA
52	Support Ship Status	SU
53	Naval Gunfire Caliber	CT
54	Naval Ordnance Type	NO
55	Firing Unit	FU
56	Inactive Target Description	TN
57	Anti-Aircraft Working Storage	AW
58	AA Characteristic	AA
59	Target Description	TD
60	Aircraft Characteristic	AC
61	A/C Ordnance Characteristic	AO
62	A/C Type 1 Standard Ordnance	SO1
63	A/C Type 2 Standard Ordnance	SO2
64	A/C Type 3 Standard Ordnance	SO3
65	A/C Type 4 Standard Ordnance	SO4
66	Target Aircraft Assignment	TA
67	Multiple A/C Activation	MA
68	Preplanned Air Strike	PP
69	Naval Gunfire Commencement & Cessation	TT
70	Orbit Point Description	OP
71	Target Type Characteristic	TW
72	Target Working Storage	TK
73	Target Coordinate	TC
74	Alert Aircraft Time Period	AG
75	Output Storage	OS

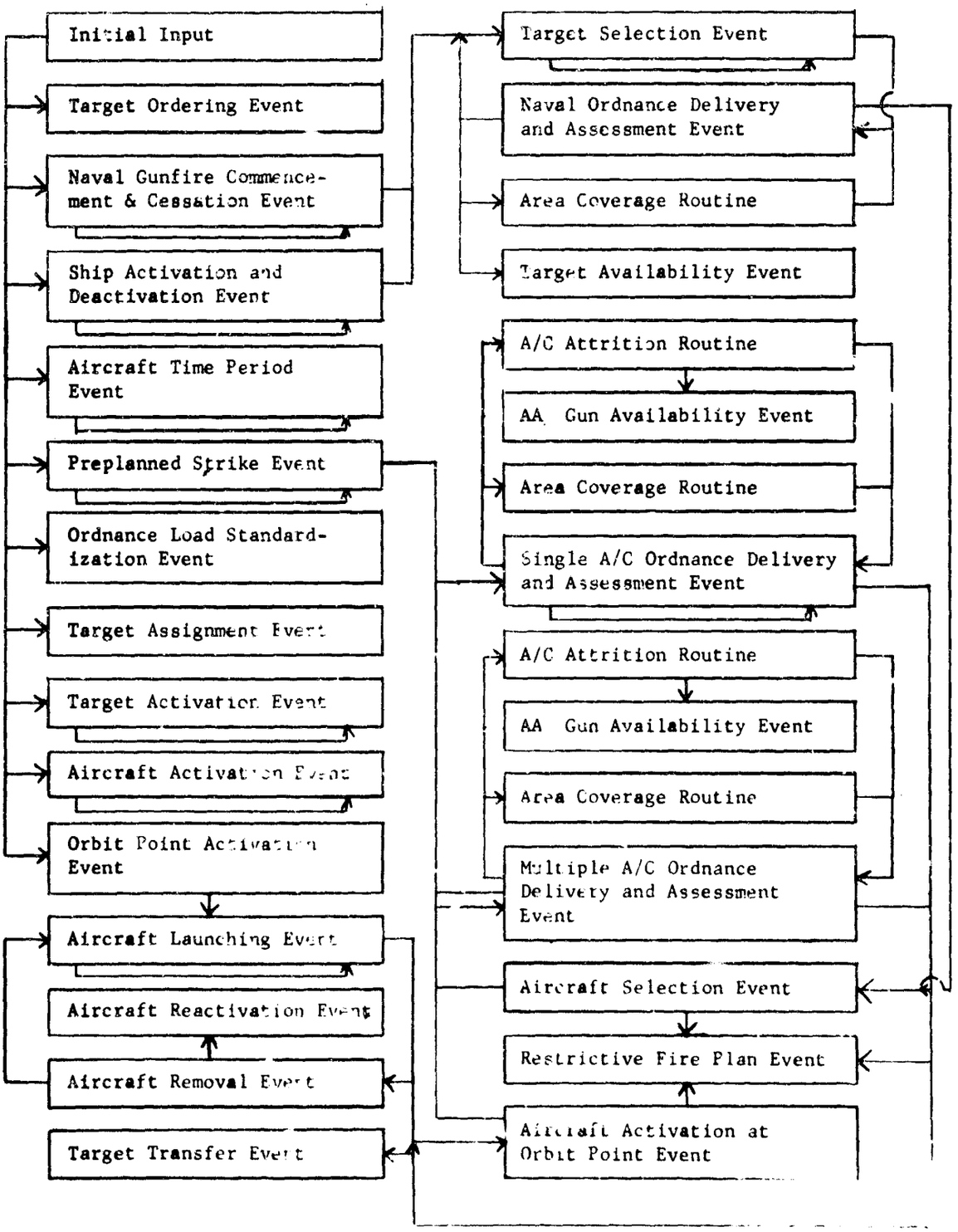
APPENDIX B

SA EVENTS

15	Output
16	End Game
50	Target Ordering
51	NGF Ordnance Delivery and Assessment
52	Ship Activation and Deactivation
53	AAA Gun Availability
54	Target Availability
55	Target Transfer
56	Aircraft Selection
57	Target Assignment
58	Target Selection
59	Multiple A/C Ordnance Delivery and Assessment
60	Single A/C Ordnance Delivery and Assessment
61	Restrictive Fire Plan
62	Aircraft Reactivating
63	Aircraft Removal
64	Preplanned Strikes
65	Aircraft Launching
66	Aircraft Activation at Orbit Point
67	Target Activation
68	Naval Gunfire Commencement and Cessation
69	Aircraft Activation
70	Orbit Point Activation
71	Ordnance Load Standardization
72	Aircraft Time Period Event
	Area Coverage Routine
	A/C Attrition Routine

APPENDIX C

SUPPORTING ARMS
EVENT FLOW SCHEMATIC



APPENDIX D

BASIC OPERATIONAL INPUT REQUIREMENTS FOR THE SUPPORTING ARMS MODEL

The following tables are not necessarily consistent with the listing in Appendix A. This is because technical data requirements have been omitted, and some of the remaining tables have been condensed into one. Sample data have been included in these tables as a means of illustration. In the event that some input values are not known, NWL will furnish these, subject to the "customer's" concurrence.

a. Assault Area Diagram - (See Tab A) This diagram should illustrate the assault land and sea area showing the enemy defensive area and sufficient sea area to include all gunfire support stations and aircraft orbit points. The assault area should not exceed 57 x 57 miles. Aircraft carriers need not be included in this diagram. However, their distance from this area should be indicated.

b. Support Ship Status Table - (See Tab B.)

c. Aircraft Carrier Table - (See Tab C)

d. Aircraft Characteristic Table - (See Tab D)

e. Target Description Table - (See Tab E)

f. Pre-planned Air Strike Period Table - (See Tab F)

g. Naval Gunfire Commencement and Cessation Table - (See Tab G.)

h. Orbit Point Description Table - (See Tab H)

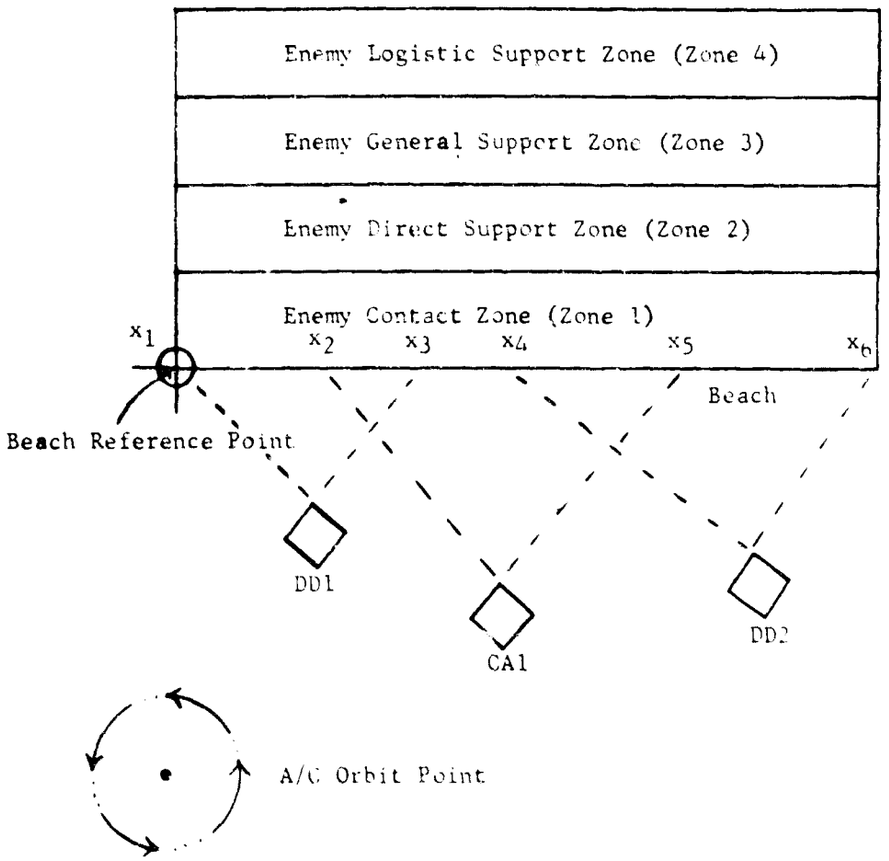
i. Assault Area Table - (See Tab I)

j. Naval Ordnance Table - (See Tab J)

k. Miscellaneous Input Table - (See Tab K)

l. Aircraft Ordnance Table - (See Tab L.)

TAB A



Coordinates of all fire support ships, orbit points, and the beach reference point should be indicated. Zones of responsibility for each ship should be indicated as above. For example, DD1 will only fire between x_1 and x_3; CA1 will only fire between x_2 and x_5; DD2 will only fire between x_4 and x_6. Each ship will fire inland as far as the range of the weapons aboard permit. If specific coordinates are not given to any enemy targets, the model has the capability to place targets randomly within their respective zones. However, if this course of action is taken, the width and depth of each of the four zones indicated above must be specified (see Tab E and Tab I).

TAB B - Support Ship Status Table

Each fire support ship should be listed according to number (say, DD1, DD2, . . ., CA1, CA2, . . ., CL1, CL2, . . ., etc.) and the following information provided.

		Sample Data	
(1)	Ship number		CA1
(2)	Number of simultaneous firing missions which can be effected by this ship.	1 1	8"/55 5"/38
(3)	Number of rounds of each type of ammunition on this ship for pre-D-day and D-day, pre-H-hour destructive fires.	4500 1500 500 400	5" HE 8" HE 5" Common 8" AP
(4)	Initial fire support position for this ship Second fire support position (if any) . . . Third fire support position (if any). . . . Fourth fire support position (if any) . . .	(a) (b) (c) (d)	_____ _____ _____ _____
(5)	Time this ship is to begin destructive fires at initial position . . . . . at second position (if any) . . . . . at third position (if any). . . . . at fourth position (if any)	 (a) (b) (c) (d)	 _____ _____ _____ _____
(6)	Time this ship is to end destructive fires at initial position . . . . . at second position (if any) . . . . . at third position (if any). . . . . at fourth position (if any)	 (a) (b) (c) (d)	 _____ _____ _____ _____
(7)	(See Tab A) Coordinates of zones of responsibility for this ship at initial position . . . . . at second position (if any) . . . . . at third position (if any). . . . . at fourth position (if any) . . . . . (NOTE: x_2 and x_5 should be expressed in terms of coordinates as well as the zones of responsibility for the remaining positions if they are used.)	 (a) x_2 to x_5 (b) ___ to ___ (c) ___ to ___ (d) ___ to ___	

These data can be arranged in a table similar to the following one.

SUPPORT SHIP STATUS TABLE

(1)	(2)	(3)	(4)	(5)	(6)	(7)
CA1	1 8"/55 1 5"/38	4500 5" HE 1500 8" HE 500 5" Comm. 400 8" AP	(a) ____ (b) ____ (c) ____ (d) ____	(a) ____ (b) ____ (c) ____ (d) ____	(a) ____ (b) ____ (c) ____ (d) ____	(a) x_2 to x_5 (b) __ to __ (c) __ to __ (d) __ to __
CA2	- - - - - - - -	- - - - - - - - - - - -	(a) - - (b) - - (c) - - (d) - -	(a) - - (b) - - (c) - - (d) - -	(a) - - (b) - - (c) - - (d) - -	(a) - to - (b) - to - (c) - to - (d) - to -
DD1 etc.						

TAB C - A/C Carrier Table

Each aircraft carrier and land base should be listed according to number (say, CVA1, CVA2, . . ., LB1, LB2, . . ., etc., where LB1 signifies land base number 1) and the following information provided.

	Sample Data	
(1) Carrier or LB number		CVA1
(2) Number of attack A/C, by type, on this carrier or land base	24 24	A4E A6A
(3) Coordinates of this carrier or land base . . .	_____	
(4) Time this carrier is available at the above coordinates to launch attack A/C	0700	D-1

These data can be arranged in a table similar to the following one.

A/C CARRIER TABLE

(1)	(2)	(3)	(4)	
CVA1	24 A4E 24 A6A	_____	0700	D-1
CVA2 etc.	- - - - - - - - - - - - - - -	- - - - - -	- -	- -

TAB D - Aircraft Characteristic Taole

Each aircraft should be listed according to number (say, A4E1, A4E2, . . ., A6A1, A6A2, . . ., etc.) and the following information provided.

	Sample Data
(1) A/C number	A6A1
(2) Carrier or base this A/C assigned to	CVA2
(3) Orbit point this A/C assigned to (if any, see Tab H)	OP1
(4) Time this A/C available for target assignment or station assignment	0600 D-day
(5) Turn about time	3 hours
(6) Standard ordnance load on this A/C	6 Mk 81 Bombs 8 Zuni Rockets 1 Bullpup A

These data can be arranged in a table similar to the following one.

A/C CHARACTERISTIC TABLE

(1)	(2)	(3)	(4)	(5)	(6)
A6A1	CVA2	OP1	0600 D-day	3 hrs.	6 Mk 81 Bombs 8 Zuni Rockets 1 Bullpup A
A6A2 etc.	- -	- -	- - - - - -	- - -	- -

TAB E - Target Description Table

Each target should be listed according to number (say, T1, T2, . . ., etc.) and the following information provided.

	Sample Data
(1) Target number	T1
(2) Target type by name	Pillbox
(3) Target width (ft.).	10
(4) Target depth (ft.) — These dimensions need not be given for standard targets such as trucks, tanks, etc.	12
(5) Target height (ft.).	3
(6) Type of fire specified (NGF or Air).	NGF
(7) NGF ordnance preferences . 1st choice	8" AP
. 2nd choice (if any) .	5" Common
. 3rd choice (if any) .	_____
. 4th choice (if any) .	_____
. 5th choice (if any) .	_____
. 6th choice (if any) .	_____
(NOTE: Only those ordnances listed will be used against the target.)	
(8) Maximum number of times to fire for effect with NGF	8
(9) Coordinates of target (if known) . . . . . (If the coordinates of the target are not known, the target will be placed randomly in one of the four zones shown in Tab A. The appropriate zone should be listed under (10) below.)	_____
(10) Depth zone (not needed if target coordinates are given in (9) above)	1
(11) Target priority	A
(12) Per cent of lethal coverage required to "kill" area target (not needed for point targets). . .	_____
(13) Should target be turned over to air or by-passed if NGF fires are ineffective (indicate Air or Bypass). (Not needed for targets originally assigned to air under (6) above.). .	Air

		Sample Data
(14) Minimum number of A/C to be used for an air strike against this target		2
(15) Maximum number of A/C to be used for an air strike against this target		4
(16) A/C ordnance preferences. .	1st choice	Bullpup A
	2nd choice (if any)	Mk 81 Bomb
	3rd choice (if any)	Mk 82 Bomb
	4th choice (if any)	Mk 83 Bomb
	5th choice (if any)	Mk 84 Bomb
	6th choice (if any)	Zuni Rocket
	7th choice (if any)	_____
	8th choice (if any)	_____
	9th choice (if any)	_____

(Note: Only those ordnances listed will be used against this target.)

(17) Time this target will be a "known" target . . (Not needed if this target is considered "known" at the beginning of the operation. By inputing specific times, surveillance acquisition rates or enemy build-up rates can be played.)	1000	D-1

These data can be arranged in a table similar to the following one.

TARGET DESCRIPTION TABLE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
T1	Pillbox	10	12	3	NGF	1st 8" AP 2nd 5" Common 3rd 4th 5th 6th	8	___	1	A	___	Air	2	4	1st Bullpup A 2nd Mk 81 3rd Mk 82 4th Mk 83 5th Mk 84 6th Zuni 7th 8th 9th	1000 D-1
T2	- - - -	-	-	-	"	1st - - - - 2nd - - - - 3rd - - - - 4th - - - - 5th - - - - 6th - - - -	"	-	-	-	-	-	-	-	1st - - - - 2nd - - - - 3rd - - - - 4th - - - - 5th - - - - 6th - - - - 7th - - - - 8th - - - - 9th - - - -	" " " " " " " - - - - - - " " - - "
T3 etc.																

TAB F - Pre-planned Air Strike Period Table

Each pre-planned air strike period should be listed according to number (say, P1, P2, . . ., etc.) and the following information provided.

	Sample Data
(1) Strike period number	P1
(2) Maximum number of Aircraft to use during this period	20
(3) Time to commence this air strike period (time at which Aircraft will be over target area).. 0700	D-1
(4) Target numbers of specific targets to be attacked	T6 T7 T8 T9 T10
(If specific targets are not listed, the number of aircraft listed under (2) above will strike targets of highest priority. If this course of action is taken, the model simulates the assignment of aircraft to existing targets of highest priority. Since in reality, these assignments would take place some time prior to the actual strike based on "known" targets at that time, the time such assignments would be made must be indicated under (5) below.)	
(5) Time aircraft will be assigned to targets (not needed if specific targets are listed under (4) above	____

These data can be arranged in a table similar to the following one.

PRE-PLANNED AIR STRIKE PERIOD TABLE

(1)	(2)	(3)		(4)	(5)
P1	20	0700	D-1	T6 T7 T8 T9 T10	
P2 etc.	-	- - - - - - - - -		-	--

TAB G - Naval Gunfire Commencement and Cessation Table

This table is needed to commence and cease firing on all active fire support ships during the pre-D-day and D-day, pre-H-hour, destructive fires. It provides for ceasing fire on all active fire support ships during periods of darkness, preplanned air strikes, etc., and then commencing fire at some later time. The following information should be provided.

	Sample Data	
(1) Time to commence NGF, 1st period	0500	D-1
(2) Time to cease NGF, 1st period	1200	D-1
(3) Time to commence NGF, 2nd period	1400	D-1
(4) Time to cease NGF, 2nd period	1900	D-1
(5) Time to commence NGF, 2nd period	0500	D-day
(6) Time to cease NGF, 3rd period	0730	D-day

.
.
.
etc.

These data can be arranged in a table similar to the following one.

NAVAL GUNFIRE COMMENCEMENT AND CESSATION TABLE

(1)	0500	D-1
(2)	1200	D-1
(3)	1400	D-1
(4)	1900	D-1
(5)	0500	D-day
(6)	0730	D-day

.
.
.
etc.

TAB H - Orbit Point Description Table

Each orbit point should be listed according to number (say, OP1, OP2, . . ., etc.). The times that air alert aircraft are to be on station at each orbit point as well as the number of aircraft for each time for each orbit point should be provided.

		Sample Data
(1) Orbit point number		OP1
(2) Coordinates of this orbit point		_____
(3) Times that air alert aircraft are to be on station at this orbit point	(a)	0600 D-1 to 1800 D-1
	(b)	0500 D-day to 0700 D-day
	(c)	_____
	.	
	.	
	.	
(4) Number of aircraft to be on station at this orbit point at the times listed under (3) above	(a)	4
	(b)	4
	(c)	_____
	.	
	.	
	.	

These data can be arranged in a table similar to the following one.

ORBIT POINT DESCRIPTION TABLE

(1)	(2)	(3)	(4)
OP1	_____	(a) 0600 D-1 to 1800 D-1 (b) 0500 D-day to 0700 D-day (c) _____ . . .	(a) 4 (b) 4 (c) _____ . . .
OP2	- - - -	(a) - - - - - - - - - - - - - - (b) - - - - - - - - - - - - - - (c) - - - - - - - - - - - - - - . . .	(a) - - - - - (b) - - - - - (c) - - - - - . . .
OP3 etc.			

TAB I - Assault Area Table

Referring to the assault area diagrams in Tab A, the following information should be provided.

	Sample Data
(1) Beach reference point coordinates	_____
(2) Depth of zone 1 (yds.)	2,000 yds.
(3) Depth of zone 2 (yds.)	8,000 yds.
(4) Depth of zone 3 (yds.)	15,000 yds.
(5) Depth of zone 4 (yds.)	30,000 yds.
(6) Width of zones 1, 2, 3, and 4 above (yds.) . . .	21,120 yds.

(Dimensions (2) through (6) above need not be listed if all targets are given specific coordinates.)

These data can be arranged in a table similar to the following one.

ASSAULT AREA TABLE

(1)	(2)	(3)	(4)	(5)	(6)
____	2,000	8,000	15,000	30,000	21,120

TAB J - Naval Ordnance Table

Each type of naval ordnance should be listed by type and the following information provided.

	Sample Data
(1) Type ordnance	5"/38 Common
(2) Number of rounds to fire for effect on point targets	12
(3) Number of rounds to fire for effect on area targets if different from (2) above	_____
(4) Estimated number of rounds to adjust on point targets	5
(5) Estimated number of rounds to adjust on area targets if different from (4) above	_____
(In items (4) and (5) above, if a specific number is not available, an interval of values will be sufficient, for example, 3 to 7 rounds.)	
(6) Estimated time to adjust on point targets	5 minutes
(7) Estimated time to adjust on area targets if different from (6) above.	_____
(8) Estimated time to fire for effect on point targets	2 minutes
(9) Estimated time to fire for effect on area targets if different from (8) above	_____
(In items (6) through (9) above, if specific times are not available, an interval of time will be sufficient.)	

NAVAL ORDNANCE TABLE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
5"/38 Common	12	___	5	___	5 min.	___	2 min.	___
5"/38 H.E.	--	---	---	---	-----	----	-----	---
6"/47 A.P.	--	---	---	---	----	----	----	---
etc.								

TAB K - Miscellaneous Input Table

The following miscellaneous information should be provided.

	Sample Data
(1) Estimated time between fires for effect on the same target	2 minutes
(2) Estimated time between different firing missions	4 minutes
(3) Estimated time to transfer target to air support if NGF fires for effect are ineffective	3-6 minutes
(In items (1), (2), and (3) above, if a specific time is not available, an interval of time will be sufficient, for example, 2 to 5 minutes.)	
(4) Length of restrictive fire zone (yds.). . .	17,600 yds.
(5) Width of restrictive fire zone (yds.) . . .	3,520 yds.
(6) Time first ground (carrier) alert aircraft become available if this concept is employed	_____
(7) Number of days in operation prior to and including D-day	2
(8) Number of fire support ships for pre-D-day and D-day, pre-H-hour fires	5
(9) Number of attack aircraft for pre-D-day and D-day, pre-H-hour support	80
(10) Total number of targets	600

This information can be arranged in a table similar to the following one.

MISCELLANEOUS INPUT TABLE

	Sample Data		Sample Data
(1)	2 minutes	(6)	_____
(2)	4 minutes	(7)	2
(3)	3-6 minutes	(8)	5
(4)	17,600 yds.	(9)	80
(5)	3,520 yds.	(10)	600

TAB L - Aircraft Ordnance Table

Each type of aircraft ordnance should be listed by type and the following information provided.

	Sample Data
(1) Type ordnance	Mk 81 Bomb
(2) Number delivered per pass point target	2
(3) Number delivered per pass area target if different from (2) above.	6
(4) Delivery altitude - point target	1000 ft.
(5) Delivery altitude - area target if different from (4) above	2000 ft.
(6) Ordnance delivery speed	450 Knots
(7) Ordnance DEP.	110 ft.
(8) Ordnance REP.	185 ft.
(9) Ordnance reliability (over-all)	.98
(If specific values for items (7), (8), and (9) are not known, existing data at NWL will be used.)	
(10) Initial strike run altitude	6000 ft.
(11) Angle of delivery with horizontal	30

These data can be arranged in a table similar to the following one.

AIRCRAFT ORDNANCE TABLE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Mk 81 Bomb	2	6	1000'	2000'	450 kts.	110'	185	.98	6000'	30
Bullpup A	-	-	- - -	- - -	- - - -	- -	- -	- -	- -	- -
5" Zuni Rocket	-	-	- - -	- - -	- - - -	- -	- -	- -	- -	- -
etc.										

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13 ABSTRACT

The U. S. Naval Weapons Laboratory, Dahlgren, Virginia, has developed a detailed event type simulation of the Supporting Arms Phase of an amphibious operation. The model has been developed for research use in making studies concerning the supporting arms phase of an amphibious operation during the pre-D-day and D-day (pre-H-hour) time period in a limited war setting, and for Fleet Operators use to determine supporting arms requirements for an amphibious assault. Programmed for the IBM 7030 (STRETCH) digital computer, the model simulates the naval gunfire and air support portions of the amphibious operation. Provisions are being made to simulate attrition to friendly attack aircraft. The model is currently operational and provides for considerable flexibility of input data and for a wide variety of studies and applications.

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